

Static Load Analysis of a Ladder Type Chassis Frame

Rakesh Kumar Sahu¹, Suman Kumar Sahu², Srikant Behera³ & V. Santosh Kumar⁴
¹Lecturer, 2,3,4Students.

Department of Mechanical Engineering, Gandhi Institute of Engineering & Technology,
Gunupur

Abstract: - Light vehicle chassis is a major component in an on road vehicle system. This research work contains modeling, design and various stress distribution for bending analysis of light vehicle chassis. The main objective is to determine the linear static stress distribution of the critical area which has highest stress of the chassis and to predict failure of the chassis. The FE analysis have been done for a light vehicle chassis model by utilizing commercial finite element analysis software packages like CATIA and ANSYS.

An attempt has been made to the study an on road lower ton vehicle, which is having a load carrying capacity of 1 ton. The equivalent stress, equivalent elastic strain and total deformation was carried out to determine stress distribution, deflection and deflection of the chassis.

Here for analysis an attempt is made by changing the cross sections for the construction of chassis like Square, rectangular and tube are considered. A complete feature based chassis model has been developed and assembled as per the fabricated structure by using CATIA software. Meshing is carried out by using ANSYS software. FE mesh model consists of geometry cleanup, 2D and 3D mesh, nodes and elements with connectivity. The FE mesh model has 3D tetrahedral shape of solid element, which will give the closeness to the accurate result. To check the mesh quality parameters like Aspect ratio, Warp, Jacobian and skew of an individual element. In order to get accurate result of the critical area of the chassis, locally finer meshing on the front and rear rail structure of the chassis has been done. Refine mesh applied on the critical region of the chassis.

According to the equation of equilibrium condition, the bending in left ramp and right ramp loads were calculated manually and applied on the FE model. Based on the FE results, equivalent stress, equivalent elastic strain and total deflection are analysed for all three cross sections.

Index Terms- Chassis, Static Analysis, FE Analysis, ladder type, Stress analysis

Introduction

Many types of pollution are there such as water pollution, noise pollution, thermal pollution and air pollution. Air pollution can be considered as one of the main hazard to the health of human being. The air pollution is due to the increasing number of vehicle use by human. When the number of vehicle increases, the usage of the petrol also increase respectively. The lack of the source of the petrol makes the price increase by time to time. The emission from the vehicle makes the environment faces the air pollution that in critical level.

Many steps need to reduce the number of the vehicle in other side to reduce the price of the petrol and to reduce the air pollution. The big number of vehicles in each country makes the prevention to reduce the number of vehicle difficult. So, the other prevention is increase the efficiency of the vehicle's engine. When the engine at the efficient level, the emission is at the low level and the most important is the usage of petrol is low. The prevention is reducing the weight of the body and chassis of each vehicle.

This paper focused to reduce the usage of petrol by design and analysis the chassis to reduce the weight of the chassis of vehicle. At the same time, the global usage of the petrol also reduced. So that a more fuel-efficient passenger vehicles can be prepared for the automobile competition market like INDIA.

Problem Definition

In the present time world is moving towards progress. People can able to afford their own vehicles. Thus the usage of transport increasing day by day on the road. The number increase due to the royal life style of people those usually choose to use their own vehicle than public transport. When the vehicle number increases, the usage of petrol (fuel) also increases. At the same time, the emission from the vehicles increases the air pollution. Also Petrol or diesel are not available plentifully. The prevention steps needed to reduce the consumption of petrol without hampering the comforts of people. One of it may be

by reducing the weight of the vehicle which can reduce the usage of petrol.

When the matter of reducing the weight of vehicle is coming we have to consider reducing the weight of the chassis as it contributes a bigger amount of load of a vehicle. If the chassis is designed in an optimal material usage then it will save the amount of material consumed for single time also the reduction in fuel cost will also be economical for customer.

As a result weight of the chassis increases. This increase in weight reduces the fuel efficiency and increases the cost due to extra material. The design of the Chassis with adequate stiffness and strength is necessary.

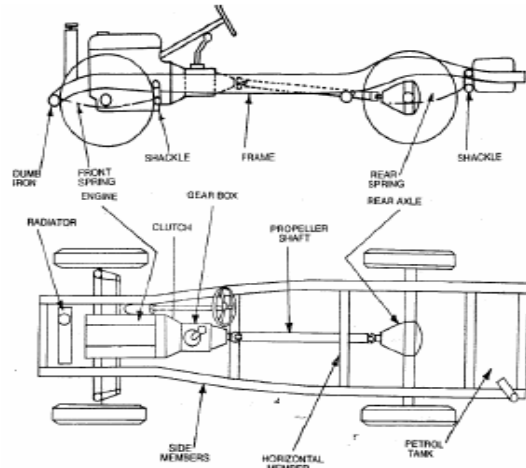
Chassis

Chassis is a French term and was initially used to denote the frame parts or Basic Structure of the vehicle. It is the backbone of the vehicle. A vehicle without body is called Chassis. A **chassis** consists of an internal framework that supports a manmade object in its construction and use. It is analogous to an animal's skeleton. An example of a chassis is the under part of a motor vehicle, consisting of the frame (on which the body is mounted). The components of the vehicle like Power plant, Transmission System consisting of clutch gearbox, propeller shaft and rear axle, Wheels and Tyres, Suspension, Controlling Systems like Braking, Steering etc. and electrical system parts are also mounted on the Chassis frame. It is the main mounting for all the components including the body. So it is also called as Carrying Unit. If the running gear such as wheels and transmission, and sometimes even the driver's seat, are included, then the assembly is described as a rolling chassis.

In the case of vehicles, the term rolling chassis means the frame plus the "running gear" like engine, transmission, drive shaft, differential, and suspension. A body (sometimes referred to as "coachwork"), which is usually not necessary for integrity of the structure, is built on the chassis to complete the vehicle. For commercial vehicles, a rolling chassis consists of an assembly of all the essential parts of a truck (without the body) to be ready for operation on the road. The design of a pleasure car chassis will be different than one for commercial vehicles because of the heavier loads and constant work use.

The automotive chassis is tasked with holding all the components together while driving, and transferring vertical and lateral loads, caused by accelerations, on the chassis through the suspension and to the wheels. The chassis of an automobile provide mounting points for the components like engine, driveline, suspension system and wheels. The

main functions of the chassis are to support the chassis components and the body to withstand static and dynamic loads without excessive deflection or distortion. As a result the weight of the chassis increases.



(Fig-1: Skeletal view of Chassis)

Classification Of Chassis

FIRST TYPE:

According to driver seat arrangement the different types of automobile chassis are as follows.

- 1. Conventional control chassis:** In which engine is mounted in front of the driver's cabin such as in cars. This type of arrangement avoids full utilization of the space. Chassis portion cannot be utilized for carrying passengers and goods. Here the driver cannot able to see the things just before the vehicle.
- 2. Semi-forward control chassis:** - In which engine is mounted that half of it is in the driver's cabin whereas the other half is in front, outside the driver's cabin as in tata trucks. In this arrangement a part of the chassis is utilized for carrying extra passengers.
- 3. Full-forward control chassis:** - In which engine is mounted completely insides the driver's cabin as in case of buses. Obviously maximum utilization of space is achieved in this type of arrangement. Here the driver can able to see the things just before the vehicle.

SECOND TYPE:

According to construction of frame the different types of automobile chassis are as follows.

1. Conventional or full frame chassis: In this type of chassis the body is made as a separate unit and then joined with ladder frame. All the systems in a vehicle such as the engine, transmission system, steering System, suspension system supported by it.

2. Non conventional or frameless chassis: In this type of chassis the ladder frame is absent and the body itself acts as the frame. It supports all the systems in a vehicle such as the Engine, Transmission system, Steering system, Suspension system. The integrated frame and body type of construction, also referred to as unitized construction, combines the frame and body into a single, one-piece structure.

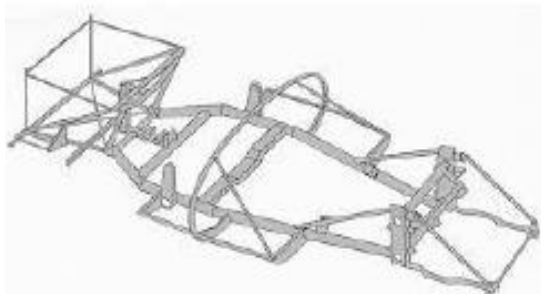
Types Of Chassis Frame

1. Ladder frame: The chassis consisted of two parallel beams mounted down each side of the car where the front and rear axles were leaf sprung beam axles. The beams were mainly channelled sections with lateral cross members, hence the name.



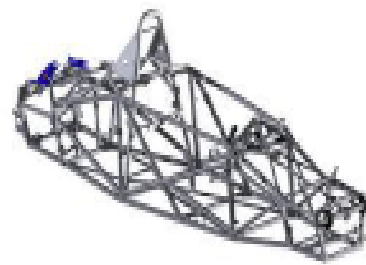
(Fig-2 Ladder Frame chassis)

2. Twin tube: It is the overall structure of the vehicle along with body made up of tubes as a closed section is torsionally more rigid than open section.



(Fig-3 Twin Tube chassis)

3. Space frame: A space frame is one in which many straight tubes are arranged so that the loads experienced all act in either tension or compression. This is a major advantage, since none of the tubes are subject to a bending load. Since space frames are inherently stiff in torsion, very little material is needed so they can be lightweight.



(Fig-4 Space Frame chassis)

Static Analysis of Chassis Frame

Here in static analysis a typical ladder frame chassis is considered. The different load considerations are taken for analysis. The chassis is designed analytically by varying materials and cross section of beam. The different cross sections are considered as

- Rectangular Section
- Square Section
- Tube Section

The different materials are chosen as

- Aluminium Alloy
- Structural Steel

Here analytical approach is considered for deciding the dimension of chassis cross section. During static condition the chassis frame is only subjected to bending loads due to the weight of the members over here. By considering the equation of bending the cross sections are decided. Then the same cross sections are analyzed by using FEM

Let us consider the condition for designing the chassis

- Kerb weight= 1800 Kg
- Gross vehicle Weight= 2800 kg
- Total load to be applied= $2800 \times 9.81 = 27468 \text{ N}$
- Considering an overload of 1.25 of total load = $27468 \times 1.25 = 34335 \text{ N}$.
- As the chassis frame has two members so load acting on each side member is half of the total load.
- Load acting on each member of frame = $\text{Total load acting on the chassis frame} / 2 = 34335 / 2 = 17167.5 \text{ N}$

Now considering loads of different components which causes bending in chassis frame is

SL NO	COMPONENT	TOTAL LOAD (KG)	LOAD PER EACH MEMBER (KG)	LOAD (N)	TYPE OF LOAD
1	Engine	230	115	1125	Point Load
2	Gear Box	50	25	245	Point Load
3	Body Weight	1000	500	4905	UDL

4	Passenger Weight	100	50	490.5	UDL
---	------------------	-----	----	-------	-----

(Table-1 Different Loading conditions for a ladder type chassis)

From the above table bending moment at different cross sections are calculated by analytical method. By this method of simple bending different dimensions of the taken cross sections for the side member of ladder frame are calculated by considering highest bending moment.

$$\frac{M}{I} = \frac{\sigma}{Y} = \frac{E}{R}$$

$$M = \frac{I}{Y} \times \sigma = Z \times \sigma$$

MATERIAL	YIELD STRENGTH	FS	WORKING STRESS	Z
Stainless Steel	205	2	102.5	35321.85
Aluminium alloy	160	2	80	45256.13

(Table-2 Section modulus value for different materials)

Here Table-3 Shows the material properties and Table-4 shows various compositions of the material considered

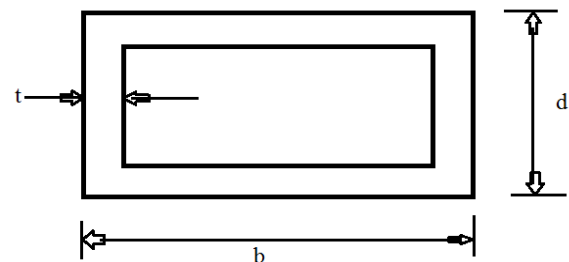
Properties Value and unit	Value & unit	
	Stainless Steel	Aluminium Alloy
Ultimate tensile strength	70 Mpa	195MPa
Density	8.0 g/cm ³	2.7 g/cm ³
Modulus of elasticity	200 GPa	69.5GPa
Shear strength	152 MPa	150 MPa
Yield strength (0.2% offset)	205 MPa	160 MPa
Melting point	1454 °C	600 °C
Elongation	35%	14%

(Table-3 Mechanical properties of Stainless Steel & Aluminium Alloy)

Stainless Steel		Aluminium Alloy	
Element	Value	Element	Value
Ni	14-16	Cr	0.1
Cr	18-20	Fe	0.35 max
C	0.08 max	Mg	0.45 - 0.9
Mo	4-10	Mn	0.1 max
Fe	Balance	Si	0.2
Mn	2 max	Ti	0.1 max
Si	1 max	Cu	0.1max
S	0.03 max	Al	Balance
P	0.04 max	Zn	0.1 max

(Table-4 Typical composition of Stainless Steel & Aluminium Alloy)

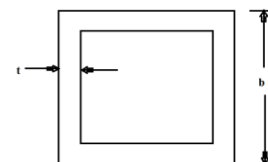
By considering the section modulus and the cross section the following dimensions are calculated for the taken cross sections.



(Fig-5 Rectangular cross section)

MATERIAL	Z (mm ³)	t (mm.)	b (mm.)	d(mm.)
Aluminium	33942.093	15.7	94.2	47.1
Steel	26491.39	14.45	86.7	43.35

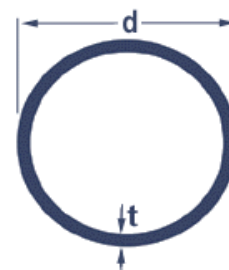
(Table 5: Dimensions for rectangular cross section)



(Fig-6 Square cross section)

MATERIAL	Z (mm ³)	t (mm.)	b (mm.)
Aluminium	33942.093	10.55	63.3
Steel	26491.39	9.71	58.26

(Table 6 Dimensions for square cross section)



(Fig-7 Circular cross section)

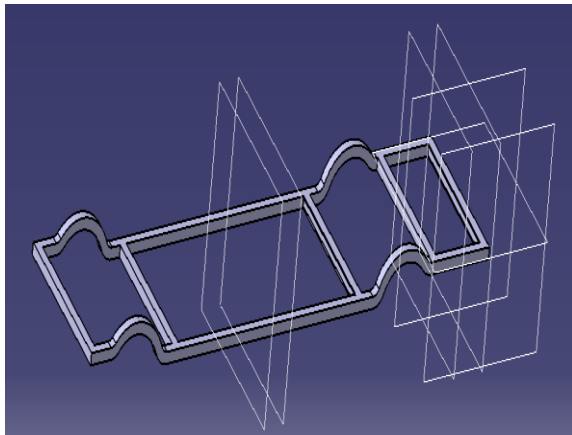
MATERIAL	Z (mm ³)	t (mm.)	d (mm.)
Aluminium	33942.093	17.93	71.72
Steel	26491.39	16.5	66

(Table 7: Dimensions for Circular cross section)

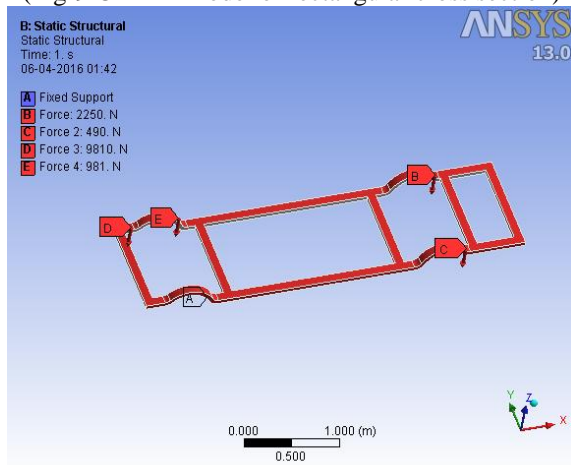
The above cross sections are designed in CATIA and then analyzed with the help of ANSYS for the values of Equivalent stress, Equivalent elastic strain and

total deformation. And the detailed datas are mentioned in table 8 and 9.

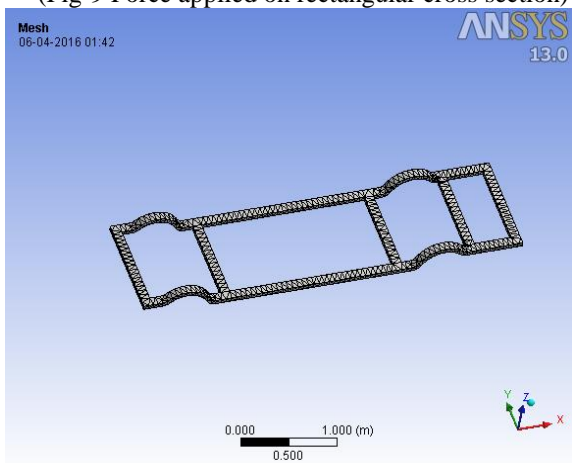
Numerical Analysis By Ansys



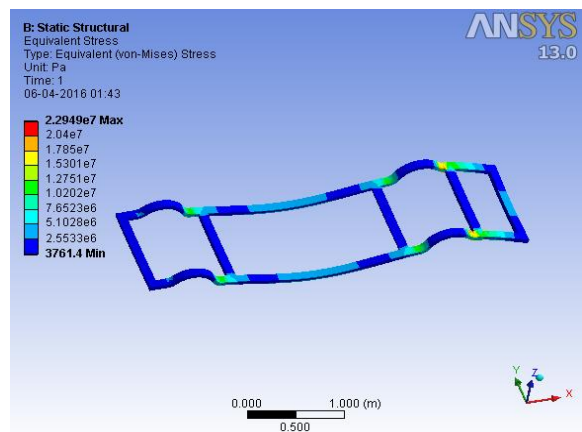
(Fig-9 CATIA Model of rectangular cross section)



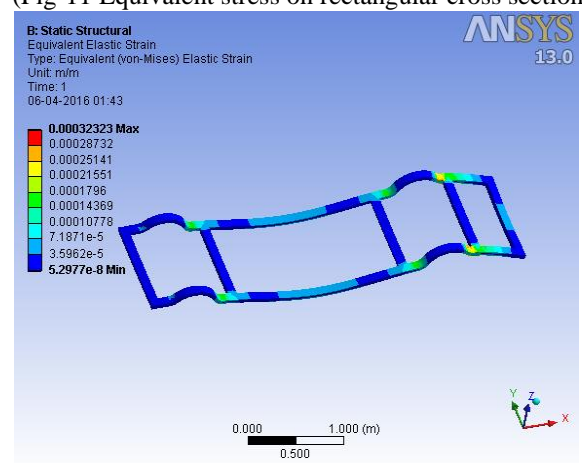
(Fig-9 Force applied on rectangular cross section)



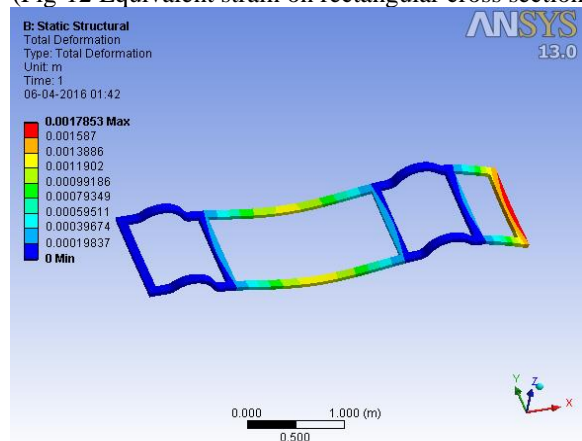
(Fig-10 meshing on rectangular cross section)



(Fig-11 Equivalent stress on rectangular cross section)



(Fig-12 Equivalent strain on rectangular cross section)



(Fig-13 Total Deformation on rectangular cross section)

After analyzing through ANSYS the following results are obtained for Equivalent stress, Elastic Strain and total deformation as indicated in table.

Cross Section	Equivalent stress		Equivalent elastic strain		Total Deformation	
	Min.	Max.	Min.	Max.	Min.	Max.
Rectangular	376 1.4	2.29 49e7	5.29 77e-8	0.0002 8732	0	0.0 015 87
Square	547 5.9	2.12 84e7	7.71 25e-8	0.0002 6648	0	0.0 012 263
Circular	281 1	2.35 98e7	3.95 92e-8	0.0003 3237	0	0.0 017 034

(Table 8: Result analysis for Aluminium Alloy)

Cross Section	Equivalent stress		Equivalent elastic strain		Total Deformation	
	Min.	Max.	Min.	Max.	Min.	Max.
Rectangular	3344. 7	2.93 25e7	1.67 23e-8	0.0001 4662	0	0.000 8945 6
Square	5447. 7	2.54 25e7	2.72 39e-8	0.0001 2713	0	0.000 6001 6
Circular	2100. 2	3.03 96e7	1.05 01e-8	0.0001 5198	0	0.000 8462

(Table 9: Result analysis for Structural Steel)

Conclusion:

After conducting the analysis in ANSYS it was found that for structural steel equivalent stress value is highest for circular and lowest for square section. Equivalent elastic strain and total deformation are lowest for square cross section where as equivalent elastic strain is lowest for circular cross section and total deformation is lowest for rectangular cross section. Whereas for Aluminium alloy equivalent stress and equivalent elastic strain behaves similarly but total deformation lowest for square cross section and highest for circular cross section.

Acknowledgements

We take the opportunity to express our heartiest thanks to Prof. Dr. A.V.N.L Sharma, HOD department of Mechanical Engineering who gave us the opportunity to carry out this project and allowed us to use the necessary equipments from the laboratory. We convey our gratitude to our project guide Mr. Rakesh Kumar Sahu who devoted his precious time and guided us to complete this project and prepare the report. We would also like to thank

all other respected Faculties for their moral and intellectual support..

References

1. Teo Han Fui, Roslan Abd. Rahman —Statics and Dynamics Structural Analysis of a 4.5 Ton Truck Chassis, Journal Mekanikal, December 2007, No. 24, 56-67.
2. K Chinnaraj, M Sathya Prasad, C Lakshmana Rao —Experimental Analysis and Quasi-Static Numerical Idealization of Dynamic Stresses on a Heavy Truck Chassis Frame Assembly| Applied Mechanics and Materials 2008.
3. S.S Sane, Ghanashyam Jadhav, H. Ananadaraj —stress analysis of compressed air vehicle chassis by feml International Journal of Engineering Science and Technology (IJEST).
4. M.S.M.Sani, M.T.Arbain, M.M.Noor, G.L.Ming, M.H.Zohari, C.K.E Nizwan & T.T.Mon —stress analysis and modal transient response of car chassis| International Conference on Advance Mechanical Engineering (ICAME09) 22~25 Jun, Concorde Hotel, Shah Alam, Selangor, 2009
5. Yongjie Lu, Shaopu Yang, Shaohua Li, Liqun Chen (2009) —Numerical and experimental investigation on stochastic dynamic load of a heavy duty vehicle| Applied Mathematical Modelling Volume 34, Issue 10, October 2010, Pages 2698–2710.